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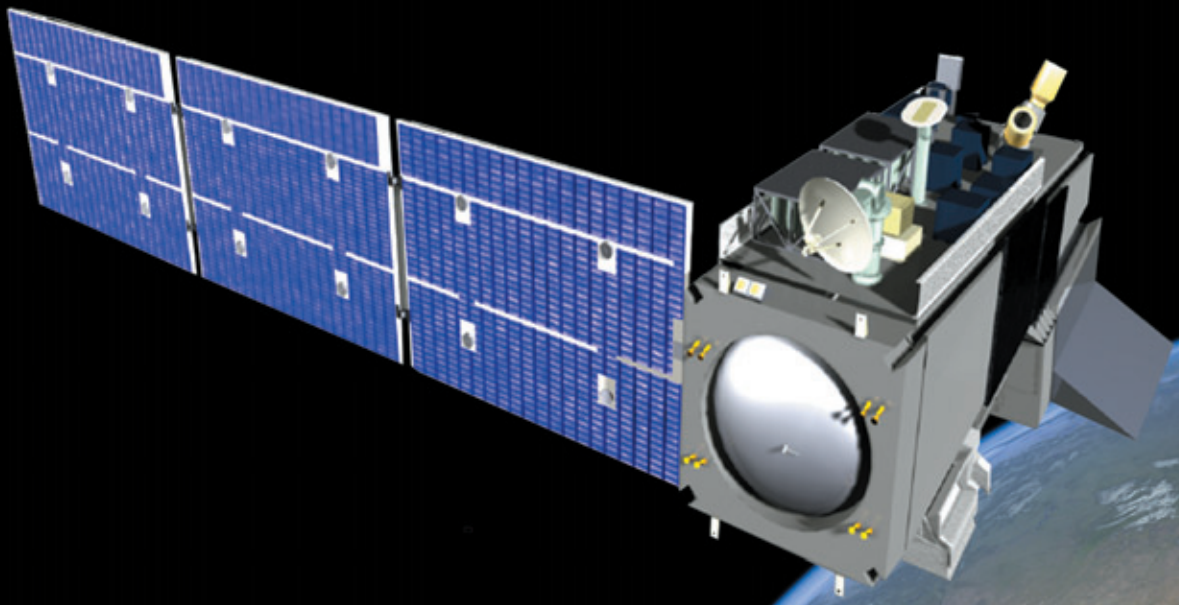

NPOESS Preparatory Project: The Bridge Between Research and Operations

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NPOESS Preparatory Project: The Bridge Between Research and Operations

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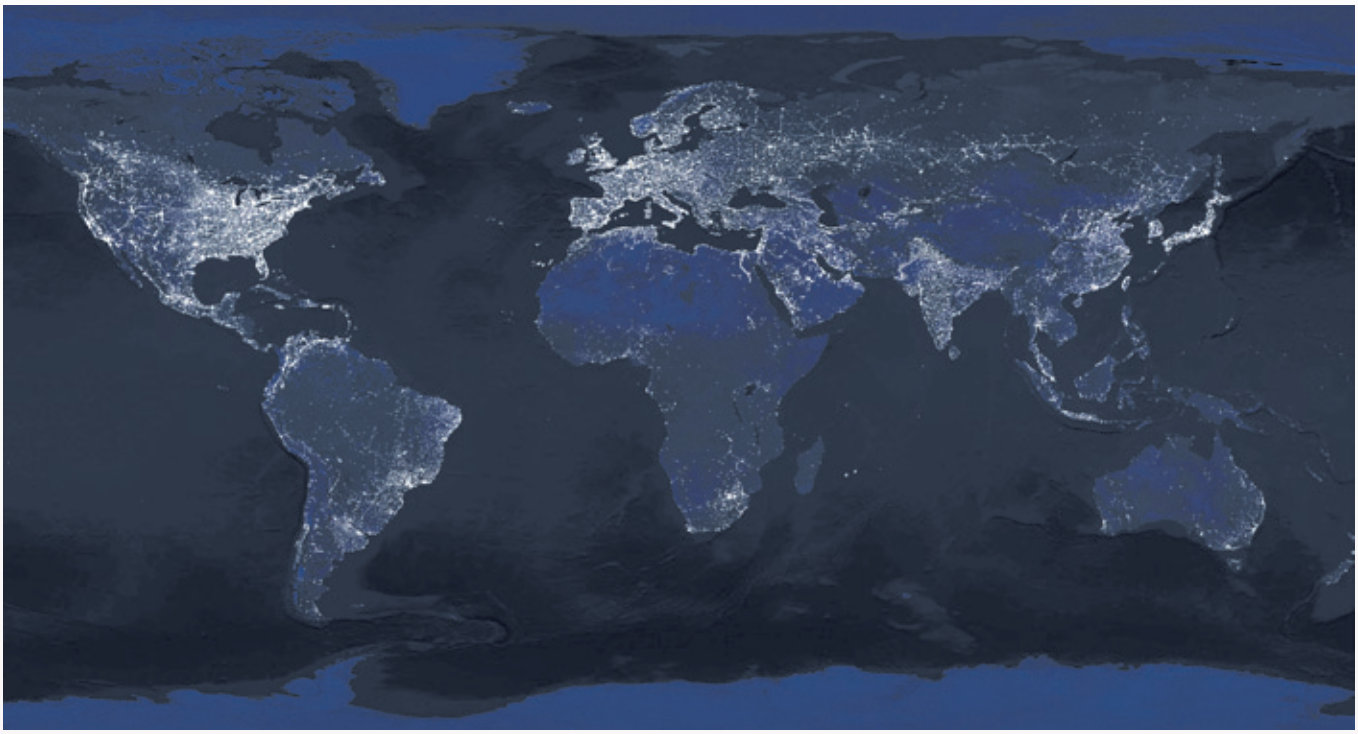
This is the third in a series of articles on the National Polar-orbiting Operational Environmental Satellite System (NPOESS). This month we review the NPOESS Preparatory Project (NPP) that will be flown as a precursor to POESS. NPP is the "Bridge" to span the transition and reduce risk as the program moves from NASA research to NOAA and DoD operations.

Cover photo: Image of the NPOESS Preparatory Project (NPP) satellite orbiting the Earth. (Satellite rendition courtesy of Ball Aerospace & Technologies Corp. Composition performed by StormCenter Communications)

Introduction

More than 40 years after the launch of the first weather satellite in April 1960, the United States is changing the way that environmental satellites are acquired, managed, and operated. Weather forecasters, scientists, and decision-makers are counting on the future converged weather satellite system, the National Polar-orbiting Operational Environmental Satellite System (NPOESS), to meet their needs for Earth science data and information in the 21st Century. NPOESS marks the transition from a time



This image showing the night lights around the world was acquired over time. Notice that there are no clouds in the image which means that a series of cloud-free images had to be "stitched" together to provide the spectacular view from space. This image was produced by overlaying images taken with the day/night band of the Operational Linescan System (OLS) instrument on the polar-orbiting Defense Meteorological Satellite Program (DMSP) spacecraft onto a cloud-free MODIS (Moderate Resolution Imaging Spectroradiometer) basemap acquired by NASA's Terra satellite.

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when polar-orbiting weather satellites were operated by two separate government agencies with separate missions to a modern cost-effective, single operational environmental satellite system providing global, simultaneous observation of the Earth system. NPOESS builds on research and technology development by the National Aeronautics and Space Administration (NASA) and will be operated by the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense (DoD) through an integrated program office.

To ensure that the research to operations transition is successful and that the best technology and instrument concepts meet both weather and climate needs, NASA and the tri-agency NPOESS Integrated Program Office (IPO) have partnered on the NPOESS Preparatory Project (NPP). NPP is a unique satellite mission scheduled for launch in October 2006 as a precursor to NPOESS. NPP serves the complementary research objectives of NASA and the pre-operational test objectives of the IPO. For NASA, NPP ensures continuity of many of the critical climate data sets begun with the launch of NASA's Earth Observing System (EOS) Terra satellite in 1999. For the IPO, NPP provides risk reduction for four critical sensors that will be flown operationally on NPOESS several years later and for the associated algorithms which convert the sensor measurements into environmental data products. NPP also serves as an early test of the NPOESS ground segments—command, control and communications, and data processing and will provide access to data from the next generation of operational sensors for early evaluation by users. Early access and evaluation will ensure that data from NPOESS will be incorporated into NOAA and DoD operations soon after its availability.

Partnerships Pave the Way

NASA and NOAA have collaborated on the development and operation of weather satellites in one of the most effective and beneficial partnerships in the United States government for more than 40 years. That partnership continues with NPP.

Due to the importance of NPOESS to the military and civilian communities, the partnering agencies in the IPO were directed to undertake a robust risk reduction effort to help ensure success of the program. Laboratory, airborne, and Space Shuttle-based efforts were considered and incorporated into the risk reduction plan. The most desirable approach was to actually test some of the NPOESS developmental sensors on-orbit in a quasi-operational environment. The IPO looked at the feasibility of flying some of the NPOESS sensors on the last of the DoD Defense Meteorological Satellite Program (DMSP) and NOAA Polar-orbiting Operational Environmental Satellite (POES) spacecraft, but available space for additional instruments, restricted fields of view, limited onboard data systems, and costs were prohibitive for these 1970s era satellites.

The NASA Earth Observing System satellites were designed to further the study of the Earth's systems and their interactions, including global climate change, through the systematic study of terrestrial, oceanic, biospheric, and atmospheric phenomena from a variety of space borne platforms. EOS Terra was launched in December 1999 to focus on land and ocean surface measurements; EOS Aqua was launched in May 2002 to improve understanding and prediction of the hydrologic cycle; and EOS Aura is scheduled for launch in June 2004 to study the Earth's ozone, air quality, and climate. Originally, NASA planned for two successor flights for each of these 6-year missions for a total of 18 years of coverage. However, the program took a new direction in 1998 that led to a strategy of careful analysis of the data from the first round of EOS missions before deciding which data sets needed to be continued.

NASA Earth Observing System (EOS)

NASA has conducted scientific observation of the Earth from space since its beginnings as an agency. In the 1970s, NASA launched the first civilian land imaging satellites; today the Landsat satellites built by NASA and operated by the U.S. Geological Survey continue the long-term record of global land cover change, providing context and calibration for the commercial remote sensing industry. NASA research based on the Upper Atmosphere Research Satellite confirmed the causes of Antarctic ozone depletion, and NASA continues a three-decade record of global ozone concentrations via the Total Ozone Mapping Spectrometer.

In 1978, NASA's Jet Propulsion Laboratory revolutionized oceanography with the launch of the short-lived Seasat, the first Earth-orbiting satellite designed for remote sensing of the Earth's oceans. Seasat included experimental passive and active instruments to measure ocean surface wind speed and direction, sea surface temperature, cloud, land and water features, the global ocean surface wave field and polar sea ice conditions, and spacecraft height above the ocean surface.

Many later Earth-orbiting instruments owe their legacy to the Seasat mission. These include the U.S./France TOPEX/Poseidon radar altimeter for measuring sea level and ocean circulation, and active scatterometer missions, such as QuikSCAT, to measure winds at the ocean surface globally. In the 1990s, NASA began deployment of the first phase of the Earth Observing System (EOS) — the world's first capability to simultaneously view the interactions of all the major components of the Earth system (land, oceans, atmosphere, ice,and life). EOS Terra was launched in December 1999 to start the series that continued with the launch of Aqua in May 2002. In June 2004, NASA's Earth Science Enterprise will launch the EOS Aura atmospheric chemistry satellite, completing the EOS first series.

The NPP mission forms the "bridge" for many climate-related measurements between EOS and NPOESS. Other missions are planned to provide similar continuity for EOS measurements not covered by NPP, such as ocean surface topography and land cover change. Many of these will also be conducted in partnership with NPOESS agencies. Currently, NASA has 18 research satellites in orbit observing various components of the Earth's system. The EOS Data and Information System distributes tens of millions of data products each year in response to millions of user requests.

Information on NASA's Earth Science Enterprise is available at *http://earth.nasa.gov/*. A wide range of Earth imagery from NASA satellites can be viewed at *http://earthobservatory.nasa.gov/*.

Renewed emphasis was put on partnering to transition these research data sets to sustained monitoring programs within operational agencies. This culminated in the NPOESS Preparatory Project, the joint mission with the IPO to carry forward selected EOS measurements while meeting the NPOESS risk reduction goals.

Dr. Ghassem Asrar, NASA's Associate Administrator for Earth Science says, "NPP represents an exciting opportunity for NASA and NOAA to combine their organization's strengths for the advancement of both science and operational needs. NPP and NPOESS capitalize on NASA's observational breakthroughs with Terra and Aqua, and NOAA and DoD's sustained operational capabilities with POES and DMSP, thus providing long-term, critical observations for understanding climate change mechanisms as well as weather."

The NPP program is jointly managed by the IPO and NASA while responsibilities for the mission are shared between the parties. NASA is responsible for:

- Mission systems engineering;
- Integration and test;
- Development of the Advanced Technology Microwave Sounder (ATMS) instrument;
- Spacecraft and integration;
- Launch vehicle and associated activities;
- Science Data Segment (SDS).

The IPO, together with the NPOESS prime contractor, Northrop Grumman Space Technology (NGST), is responsible for:

- Visible/Infrared Imager Radiometer Suite (VIIRS);
- Cross-track Infrared Sounder (CrIS);
- Ozone Mapping and Profiler Suite (OMPS);
- Command, Control, and Communications Segment (C3S);
- Interface Data Processing Segment (IDPS);
- NPP mission operations.

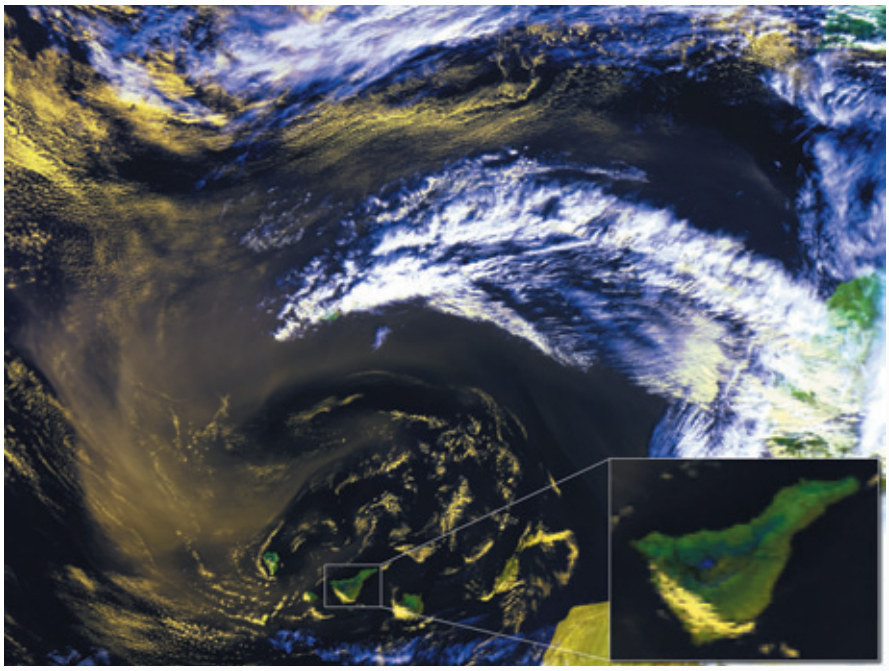
NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) is responsible for:

- Archive and Distribution Segment (ADS).

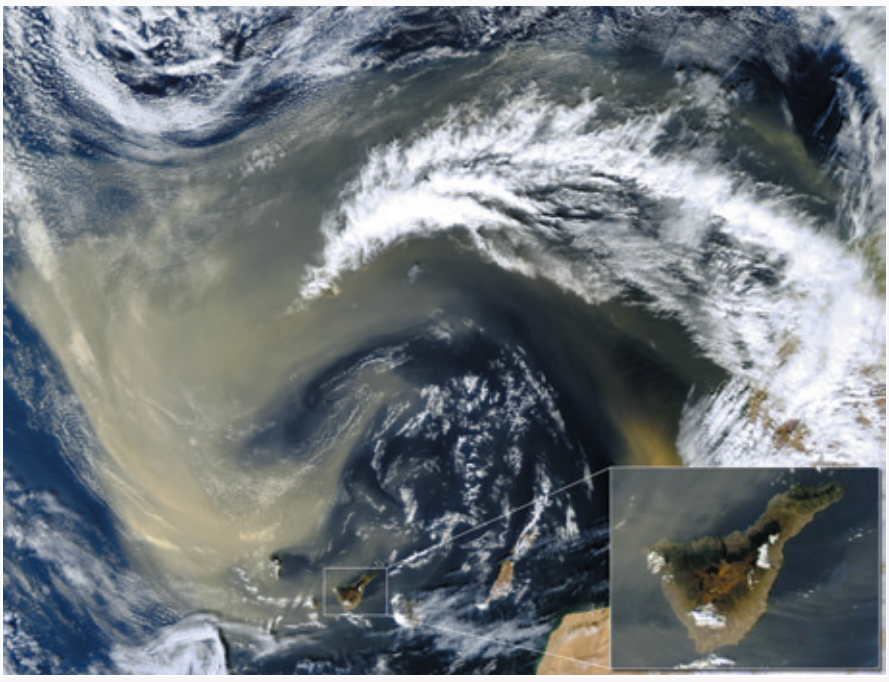
The ADS will provide users access to near real-time and archived data from NPP.

Continuity of Data: The Basis for Climate Research

Remote sensing of the planet has generated science records that now represent decades of continuous observations of the atmosphere, oceans, and land. Much like a medical record in



This AVHRR image captured by polar satellite NOAA-17 shows the airborne dust moving off the coast of Morocco into the Atlantic on February 18, 2004. This image was taken at 11:22 GMT (06:22 AM EST). The dust is discernable in higher concentrations from NOAA-17 with a maximum image resolution of 1 km at nadir. The zoom-in shows the Teide volcano in the island of Tenerife (Canary Islands). Image processed by StormCenter Communications. NOAA-17 data retrieved from the National Oceanic and Atmospheric Administration (NOAA) Satellite Active Archive (SAA).



Captured on February 18, 2004 at 14:05 GMT (09:05 AM EST), this image clearly shows the higher resolution of the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on board the NASA Aqua satellite. NPP will carry the VIIRS sensor for imaging with a maximum resolution of 370m at nadir. VIIRS will be a major improvement over current operational AVHRR and MODIS imagers as it will image at a near constant horizontal resolution across its ~3000 km swath. Shown here is a MODIS image at 250m resolution at nadir. The zoom-in shows the Teide volcano in the island of Tenerife (Canary Islands). Image processed by StormCenter Communications. Aqua data retrieved from the MODIS Land Rapid Response system, GSFC, NASA.

human health care, this Earth "record" is essential to assemble and understand the long-term history of the planet and its dynamic climate.

NPP will play a significant role in continuing and maintaining the long-term Earth environmental data record into the NPOESS era. NPP will be in orbit in advance of the expected end-of-life of EOS Aqua (~2008), and should provide significant overlap with the first NPOESS spacecraft. NPP will be an effective "bridge" between the Terra and Aqua EOS missions and NPOESS with numerous opportunities for cross-calibration and validation among existing sensors and the advanced instrumentation for NPOESS.

For climate researchers, NPP and NPOESS will be the sources for much of the satellite-derived climate data in the future. Selected near real-time Environmental Data Records (EDRs) from NPP and NPOESS will form the basis of Climate Data Records (CDRs). The quality of these EDRs for climate research will be validated during the NPP mission by NASA's Science Data Segment (SDS).

NASA's goal, through partnership with the IPO, is to maintain the space-based climate record by having research-quality measurements on operational environmental satellites. In the long-term, beyond the EOS Terra and Aqua missions, NASA will rely on NPOESS for systematic global mapping of the Earth's surface at moderate resolution. NOAA initiatives for use of NPP and NPOESS data for climate monitoring will be the subject of a forthcoming article in this series.

NPP Keystone Sensors and Systems

The four instruments selected for flight on the NPP spacecraft trace their heritage to NASA instruments on EOS Terra, Aqua, and Aura, but push the technology envelope even further. The following sensors are designed to perform imaging, atmospheric sounding, and ozone monitoring functions and are identified below:

VIIRS—Visible/Infrared Imager Radiometer Suite

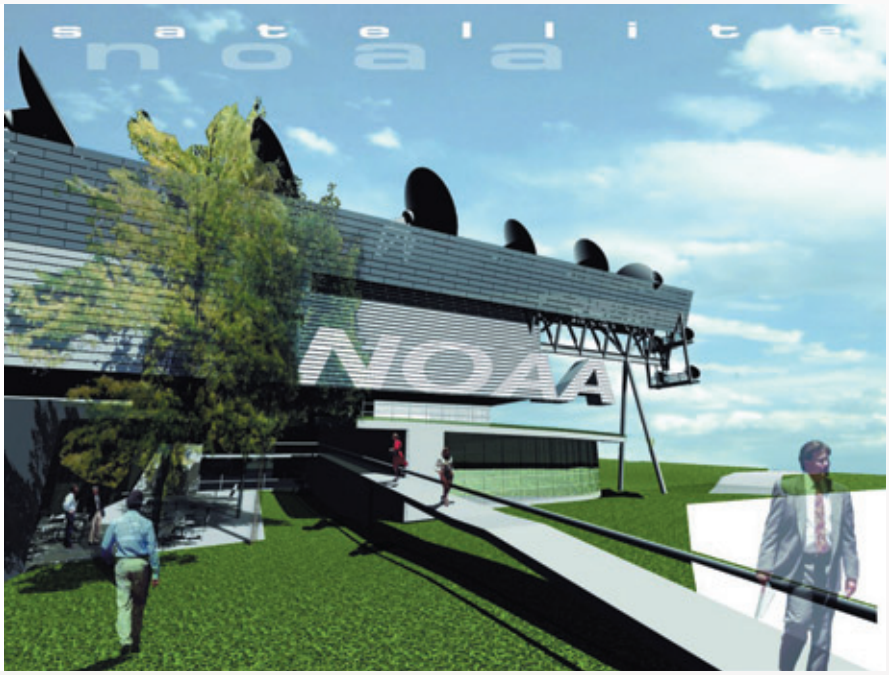
The VIIRS imager on NPP is the follow-on instrument to the imagers on DoD's DMSP, NOAA's POES, and the EOS Terra and Aqua satellites. The constant resolution Operational Linescan System (OLS) imager on the DMSP satellite contains only three channels; visible, infrared, and a day/night band. The day/night channel detects low levels of visible-near infrared radiance at night from sources on the Earth's surface, including clouds illuminated by moonlight. Detection of these types of features can be critically important for military operations. The OLS can also detect lights from cities, towns, industrial sites, gas flares, heavily lit fishing boats, and fires. This low-light capability will be carried forward to VIIRS on NPP and NPOESS, but at a much higher horizontal resolution than is currently available.

The VIIRS (being developed by Raytheon's Santa Barbara Remote Sensing (SBRS) Group, the same company that manufactured the Moderate Resolution Imaging Spectroradiometer (MODIS) that is on EOS Terra and Aqua) will fly on NPP as well as on all NPOESS platforms. VIIRS will provide complete global coverage in one day over the visible, short, mid-, and long-wave infrared regions at horizontal spatial resolutions of 370m at nadir. In addition, VIIRS will image at a near constant horizontal resolution across its ~3000 km swath, a significant improvement over the Advanced Very High Resolution Radiometer (AVHRR—on POES) and MODIS instruments. VIIRS will produce environmental data such as sea ice, sea surface temperature, ocean color, aerosols, albedo, cloud parameters, vegetation, and surface type.

CrIS & ATMS—Atmospheric Sounders

The atmospheric sounders on NPP consist of the CrIS (Cross-track Infrared Sounder) and the ATMS (Advanced Technology Microwave Sounder). Together these make up the Cross-track Infrared and Microwave Sounding Suite (CrIMSS). The suite will be used to provide vertical profiles of atmospheric temperature, humidity, and pressure from the surface to the top of the atmosphere. The CrIS, a Michelson Interferometer-based sensor, is being developed by ITT Aerospace of Fort Wayne, Indiana. CrIS will succeed the Atmospheric Infrared Sounder (AIRS) which operates on EOS Aqua and the operational High Resolution Infrared Sounder (HIRS) on POES. As the follow-on instrument to AIRS, CrIS is designed to provide vertical temperature profiles at 1° K accuracy for 1 km layers in the troposphere, a standard currently being achieved by AIRS globally and approximating the accuracy of the data obtained from radiosondes, which are carried aloft by weather balloons. Radiosondes collect critical weather information through many atmospheric layers and are what world-wide weather services have traditionally used to initialize their weather forecast models.

The ATMS is a 22-channel passive microwave sensor that will scan



NOAA is building a new $61 million Satellite Operations Facility in Suitland, Maryland. The new building is expected to open in 2005 and will house current and future environmental satellite operations of national and global significance. This new facility will be the nerve center for NOAA's next-generation satellite series (NPOESS and GOES-R) and will replace NOAA's satellite operations currently located in the World War II era Federal Office Building 4. Image courtesy NOAA.

synergistically with CrIS and provide soundings even in the presence of clouds. The ATMS is being built by Northrop Grumman Electronic Systems (NGES) in Azusa, California as the successor to the Advanced Microwave Sounding Units (AMSU which have flown on NOAA satellites since the mid- 1990s and are currently aboard EOS Aqua. By using state-of the-art technologies, the functionality of three AMSU units (AMSU- A1, A2, and Microwave Humidity Sounder-MHS) will be compressed into a single unit with a payload mass savings of 100 kilograms.

Ozone Mapping & Profiler Suite

The Ozone Mapping and Profiler Suite (OMPS) on NPP consists of two sensors; a nadir pointing scanner that will be used to obtain measurements of the total column ozone and a limb scanner which looks past the forward edge of the spacecraft to obtain vertical profiles of ozone in the Earth's stratosphere. Both units operate in the ultraviolet (UV) portion of the spectrum. The OMPS is being developed by Ball Aerospace and Technologies Corporation in Broomfield, Colorado, the same company that built the Solar Backscatter Ultraviolet Radiometer 2 (SBUV/2) instrument that is on the NOAA POES. Heritage for the nadir total column scanner goes back to the Total Ozone Mapping Spectrometer (TOMS), which first flew on Nimbus-7 in 1978 and has been flown three more times since then, as well as to the Ozone Monitoring Instrument (OMI) that will fly on EOS Aura in June 2004. The TOMS has been used to identify and monitor the changes in the ozone hole over Antarctica. The technology for the limb-profiling unit is derived from the Shuttle Ozone Limb Scanning Experiment (SOLSE) that flew on NASA's Space Shuttle missions STS-87 in 1997 and STS-107 which was lost tragically on February 1, 2003. The UV limb scanner is intended to provide vertical profiles of ozone concentrations for 3 to 5 km thicknesses of the atmosphere as compared to the 7 to 10 km thicknesses obtained from the SBUV/2 on NOAA POES. Data collected by OMPS will help fulfill U.S. treaty obligations under the Montreal Protocol to monitor ozone depletion in the atmosphere and determine if synthetic chemicals are affecting the Earth's climate and its habitability.

NPP Spacecraft

The NPP spacecraft being developed by Ball Aerospace under contract to NASA is a variation of Ball's commercial spacecraft design used by NASA in prior Earth Science missions such as QuikSCAT (Quick Scatterometer) and ICESat (Ice, Cloud, and Land Elevation Satellite). The launch is planned for October 2006 from Vandenburg Air Force Base, California. A Delta II launch vehicle will be used to inject NPP into an 824 km, sun-synchronous polar orbit with a 1030 AM descending equatorial nodal crossing time. The mid-morning crossing time was chosen to take advantage of minimum cloud cover over land surfaces. Although average cloudiness in the mid-morning differs little from the mid-afternoon, there tend to be almost twice as many days with less than 10 percent cloud cover in the mid-morning than mid-afternoon. The expected mission duration for NPP is five years with 7.5 years of consumables (*i.e.*, fuel for orbital station keeping of +/-10 minutes of equatorial nodal crossing time).

The satellite will be commanded from the NPP-NPOESS Mission Management Center (MMC) in Suitland, Maryland. The MMC is the heart of the NPOESS Command, Control and Communications Segment (C3S), developed by Raytheon Space Systems in Aurora, Colorado.

Global, or stored mission, data will be down-linked at X-band frequencies (8212.5 MHz) to a 13-meter ground receiving antenna located at Svalbard, Norway. Unlike the SafetyNet communications network that will acquire NPOESS data, NPP will have only one data receiving station at Svalbard which is located at high enough latitude (78 degrees north) to be able to "see" all 14 daily NPP satellite passes. Real-time data will also be broadcast on a continuous basis via an X-band (7750-7850 MHz) High Rate Data (HRD) link. Anyone with a ground station designed to receive and process NPP data will be able to do so when the satellite comes into range of the receiving antenna.

The global data will be transmitted from Svalbard within minutes to the U.S. via a fiber-optic cable system that was completed in January 2004 as a joint venture between the IPO, NASA, and the

Svalbard Satellite Station (SvalSat) located on Plateau Berget, Spitzbergen Island, Svalbard, Norway. The three antennas on the left (front to back) support NASA (EOS Terra and Aqua, QuikSCAT, and Landsat-7) and European Space Agency (ENVISAT – ENVironment SATellite) missions. The two antennas in the right foreground were installed to support the European Organisation for Exploitation of Meteorological Satellites (EUMETSAT) Metop satellite that will be launched in 2005. The structure in the right background is the location of a new antenna that was completed in 2003 (after this photo was taken) to support NPP and NPOESS. SvalSat (at 78° N) is ideally located to "see" all 14 daily passes of satellites in low-earth polar orbit. The town of Longyearbyen (population ~1,100) is about five miles away at the foot of the plateau. SvalSat is owned and operated by Kongsberg Satellite Services (KSAT), a Norwegian company owned jointly by the Norwegian Space Centre and Kongsberg Defence and Aerospace. Photo courtesy Kongsberg Satellite Services.

Norwegian Space Centre. NPP will generate approximately 1.5 terabytes of data per day, which is similar to the current data volumes from EOS Terra and Aqua. The four sensors on NPP will provide 80 percent of the data rate assigned to all fourteen sensors on NPOESS. This will be a significant step toward completing the data handling processes needed to accommodate even more data when NPOESS comes online.

NPP's four sensors will also provide 25 of the 55 NPOESS Environmental Data Records (EDRs). Once the data stream is in the U.S., the Raw Data Records (RDRs) will be processed into Sensor Data Records (SDRs) and EDRs by the Interface Data Processing Segment (IDPS), also being developed by Raytheon Space Systems in Aurora, Colorado. Raw Data Records (Level 0/1A) will be full resolution, unprocessed sensor data, time-referenced, with earth location, radiometric and geometric calibration coefficients appended, but not applied, to the data. Sensor Data Records (Level 1B) will be full resolution sensor data that are time referenced, earth located, and calibrated. Environmental Data Records (Level 2) are fully processed sensor data that contain the geophysical parameters or imagery that must be generated as user products. All three levels of data records (RDRs, SDRs, and EDRs) will be available to users.

Two IDPS systems will be installed to support NPP at operational weather facilities (Centrals): NOAA's NESDIS in Suitland, Maryland for processing and distribution of data to civilian organizations; and the Air Force Weather Agency (AFWA) in Omaha, Nebraska to support the military. By the time the first NPOESS is available for launch in late 2009, IDPS systems will also be located at U.S. Navy facilities in Monterey, California and at Stennis Space Center in Bay St. Louis, Mississippi. All records from NPP will be archived by NOAA from which access can be obtained by other agencies and the public.

Calibration/Validation: Solid Support for Science

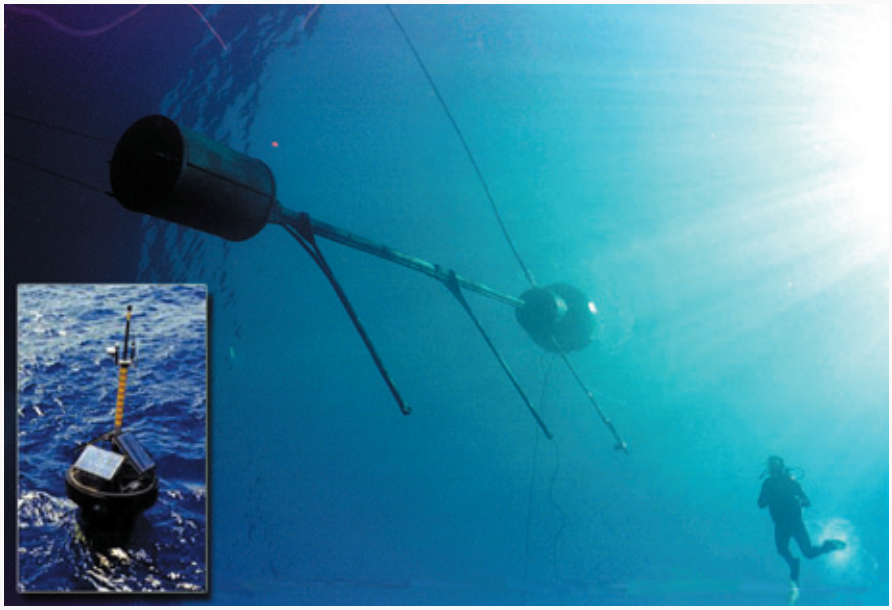
NPP has already passed important milestones on its path to the launch pad. This includes a Critical Design Review in October 2003 for the systems and the overall mission and a successful Mission Confirmation Review in the fall of 2003 that moved NPP into the implementation phase. A calibration/validation plan for NPP has been drafted and selected "ground-truth" assets, such as the NPOESS Airborne Sounder Testbed, are already deployed. A NASA NPP Science Team was competitively selected in September 2003 and had their inaugural meeting in November 2003. As the "bridge" between EOS and NPOESS, NPP will provide "lessons learned" and allow for any required modifications to hardware systems or algorithms in time to support readiness for the first NPOESS launch.

Continuity of data from EOS to NPOESS will require calibration of the NPP instruments and validation of algorithms following EOS-type approaches and cross-calibration of these instruments on-orbit with the corresponding EOS instruments (*e.g.*, VIIRS and MODIS; CrIS and AIRS; ATMS and AMSU/MHS). NPP will allow scientists to develop, evaluate, and modify NPOESS algorithms using data collected by actual sensors on orbit instead of having to approximate data through synthetic generation, as is usually done for new sensors.

To facilitate these sensor calibration and algorithm validation efforts, certain "ground-truthing" activities have been initiated for programs such as EOS (*e.g.*, MODIS) and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). For example, in the area of ocean color, these activities include the Marine Optical Buoy (MOBY), coastal and island site augmentations of the Aerosol Robotic Network (AERONET), calibration round-robins, bio-optical and atmospheric field data archives, and development and evaluation of *in situ* measurement protocols. Experience gained during these programs has demonstrated that such calibration activities for NPP and NPOESS will be essential for establishing algorithms that meet science accuracy requirements; for conducting pre-launch sensor characterization and post-launch validation; and to evaluate on-orbit sensor performance.

Taking Research into Battle

A primary mission of NPP is to test and deliver high resolution imaging and sounding data to operational users so that they can familiarize themselves with the new capabilities and prepare for NPOESS. The IDPS system at NESDIS will deliver more accurate and timely data for use in NOAA's numerical weather prediction models that support a wide variety of civil applications. A second IDPS system at the Air Force Weather Agency is intended to provide direct support for military operations. But the military is not waiting for the arrival of NPP to realize the benefits of advanced remote-sensing technologies. For example, the Naval Research Laboratory in Monterey, California has already processed MODIS



Monitoring ocean color, the Marine Optical Buoy (MOBY) is moored off the coast of Lanai, Hawaii to measure visible and near-infrared radiation entering and emanating from the ocean. MOBY provides a time-series database for development, calibration, and validation of bio-optical algorithms for use with space-based imagers such as MODIS and SeaWiFS. MOBY is a vicarious calibration facility for ocean color sensors developed by NASA. MOBY is funded jointly by NASA and NOAA. Images courtesy Dennis Clark, NOAA/NESDIS Office of Research Applications.

data from NASA's EOS Terra and Aqua satellites. The data provided time-critical information about sandstorms and water clarity to U.S. forces operating in the Persian Gulf, Arabian Sea, and Indian Ocean. This cooperation came about due to the work done by the IPO, NOAA, NASA, and the DoD in planning for NPP.

Despite the technological sophistication of today's "smart" weapons and support systems, all are impacted directly or indirectly by weather and environmental situations. The data from NPP and NPOESS will help shift the tactical and strategic focus from "coping with weather" to "anticipating and exploiting" atmospheric and space environmental conditions for worldwide military advantage. For the warfighter, this should translate into more reliable long-term planning, more efficient selection and use or performance of weapon systems which are sensitive to weather, fewer aborted sorties, reduced munitions expended and, most importantly, reduced casualties. The improved capabilities from NPOESS for weather "intelligence" will be explored further in the next issue.

NPP will provide significant risk reduction to the NPOESS mission, important data continuity to NASA's and NOAA's climate mission, and accelerate the delivery of improved data from advanced technologies to users while facilitating user preparation for the NPOESS era.

For more information about NPP visit these two websites: *www.npoess.noaa.gov* and *http://jointmission.gsfc.nasa.gov/*.

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